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THE MICROSCOPIC FLORA OF THE HUMAN MOUTH.

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I - INTRODUCTION

Over the centuries man has gradually devised methods of combatting the elements of his environment. He has learned the cultivation of the land, the domestication of the animals, and the braving of the sea, but until the nineteenth century, disease, the greatest menace to mankind, was still a matter of superstition and speculation. During the seventeenth century the first useful magnifying lenses were ground and the new era of the microscopic came into focus when Anthony van Leeuwenhoek published his observations of the protozoa and bacteria he found in his environment. As investigations progressed, a knowledge of the numbers and kinds of microorganisms increased, until a detailed system of classification was necessary.

From all the surfaces of the body, its external openings, and the tracts of the respiratory and digestive systems microorganisms have been recovered. For each of these regions typical organisms have been described. The normal flora is somewhat variable from person to person, and from place to place, and also from time to time in the same individual--(Topley and Wilson 1936). The knowledge of the flora of any area is also limited by the methods used to determine it,-as any one stain or culture medium will not be suited to all organisms.

A knowledge of the normal flora is useful for many reasons: first, to distinguish it from specific pathogens which enter from the outside; second, because normal inhabitants may cause infection under certain conditions, such as wounds, or after a primary infection has weakened the individual's resistance; third, the products of the growth of these organisms may affect the body, as in the decalcification of the teeth from acids produced by mouth organisms.

In this paper those organisms which make up the flora of the mouth under normal conditions, and those present in infections, will be considered. The mouth is an excellent habitat for microorganisms because of its structure, which affords places for anaerobes as well as the commoner aerobes, its nutrient material composed of epithelial cells which are constantly being sloughed off, the organic residue from food which is always present, the mucous, and the moisture supplied by the saliva.

Since the organisms of the environment have access to the mouth in varying degrees all the known ones have been recovered from it. Because it harbors and disseminates disease organisms and acts as a focus

of infection for other parts of the body, an understanding of its flora can not be over emphasized.

In the early years of bacteriological study the pathogens were the only organisms with which investigators were concerned. Lately, however, the microorganisms normally present have been receiving more recognition in an effort to discover their significance in the health or disease of the individual.

One of the greatest problems in the history of mouth disease is the cause of the gradual process of dental decay. The results of this decay have been known and recorded since earliest times, and up to the present an enormous amount of research and extensive reviews of the literature have been undertaken. The theories of the investigators have included the effect of diet, the presence of minerals, such as fluorine in the drinking water, and the action of bacteria. Today there are still numerous theories, some of which have proven useful in certain cases, for the cure and prevention of these dental caries, but there has been relatively little agreement among the independent investigators as to the etiological agent of the disease.

A review of the literature from ancient times through the middle of the nineteenth century reveals the sparseness of the knowledge of the microscopic flora of the body. A tremendous increase in the discovery of organisms, and an interest in the mouth's flora occurred in the latter half of the century. Since that time the quantity of literature has increased and the quality of the literature and the research has improved with the development of better techniques and a fuller understanding of the problem. It is with this period that the

main part of the paper will be concerned, with emphasis on the works published since 1930. The normal flora will be considered under the general types of organisms in the mouth and inhabitants of special areas, such as the saliva, the teeth, and the gums.

My research has been chiefly observation on the occurrence of yeasts in the normal mouth, their relation to the pH of saliva and their possible relation to dental caries. The role of the mouth organisms under abnormal conditions makes up the second division of the body of the thesis. These conditions include lowered resistance of the individual, post-operative infections, and infections of the teeth, gums, and mucous membranes.

11 - HISTORICAL

The Egyptians contributed the first writings on the diseases of the mouth, (MacNevin and Vaughan 1933) which many centuries later were shown to be caused by microorganisms. In the Ebers Papyrus, the oldest collection of medical knowledge, written about 1500 B.C., dental and gingival diseases were considered, their cause was ascribed to a variety of factors, and many crude methods were prescribed for alleviating the pain connected with them. An interesting study made on the mummies of the predynastic period showed that the condition of the teeth of the different classes of society varied as they do today. In general, those of the poorer classes had good teeth while the wealthier classes suffered from caries and pyorrhea. Their findings indicate a dietary basis for the cause of caries, but investigators of the subject are today still undecided in regard to the etiology of the disease. About a thousand years after the Ebers Papyrus was completed dentistry as a science had spread throughout Egypt.

In China, the strange ideas of the people concerning anatomy and physiology were equalled by their ideas of therapeutics. Nothing of importance to medical science has come from the early days of Chinese medical lore, although as early as 2697 B.C. the emperor Houang-ly was the founder of their medicine and dealt with many maladies of teeth and gums--(MacNevin and Vaughan 1933).

The beginnings of scientific research and the first remarkable advances in medicine occurred in the time of the famous Greek, Hippocrates, whose writings were considered authoritative until the nineteenth century. The explanation by Hippocrates of focal infection was one of the first great contributions to medical knowledge. Cancer of the mouth was discussed, but was probably one produced by trauma.

In 401 B. C. due to an epidemic of sore mouth, with symptons identical with those of Vincent's infection, the Greek army had to retreat from Asia (Prinz 1935).

With the arrival of the Greeks in Rome, advance in dental work began. Marcus T. Varro (Bulloch 1938) during the time of Cicero advised against living near marshy lands where minute animalcules are harbored which invade the body through the mouth and nose and cause disease.

Except for the spread of the findings of the Greeks and Romans by the Arabs there was little advance in knowledge in this field during the Middle Ages.

In 1543 Fracaster advanced the belief that organisms too minute to be seen were the cause of dental caries. He also published a work on the nature of disease organisms, and the mode of transmission of infectious diseases which was an astonishing guess at the existence of bacteria (Ford 1939).

Anthony van Leeuwenhoek (Bulloch 1938) in 1683 published his findings on bacteria and protozoa in his letters to the Royal Society. His experiments with the material obtained from his own mouth, especially in the region around the teeth, were the first which demonstrated the presence of microorganisms in the body. He used a crude microscope and

obtained a magnification of 160X and in estimating the sizes of organisms chose various every day objects for comparison. Regardless of the inaccuracy of his measurements he conveyed the idea of their minuteness. The organisms he observed were the common forms of mouth bacteria known today, for which he drew clear pictures and gave accurate descriptions. The figures he submitted to the Royal Society (Dobell 1932) contained a motile bacillus, Selenomonas sputigena, micrococci (found in unlimited numbers), Leptothrix buccalis, and a spirochete form, probably Spirocheta buccalis, which was the largest form found in this situation. In an attempt to eliminate the microorganisms in his mouth he washed it with a vinegar solution and found that only the superficial organisms were affected. In all the mouths, clean or dirty, which Leeuwenhoek observed, he found the microorganisms to be present, and he judged their number to be limitless. He did not make any application of his findings to disease. The theoretical connection was made immediately by others, but the discovery had no practical use until a century and a half later.

In the French army at the end of the eighteenth century an epidemic of Vincent's infection was described, but not until a century later were the organisms associated with it described, (Prinz 1935). "After Leeuwenhoek's discoveries two main directions were indicated, first the study of the nature and classification of these organisms, and secondly the relation of bacteria to fermentation, putrefaction and disease". (Zinsser and Bayne-Jones 1939).

From the end of the eighteenth century and through the nineteenth hosts of microorganisms were being described as methods of investigation improved. On the mucous membranes Leptothrix buccalis,

originally discovered by Leeuwenhoek was rediscovered by Buelmanin (1840). In 1841 Berg, and in 1842 Gruby independently found *Odium albicans* in Thrush, a throat disease. The larger parasites of the skin and mucous membranes were observed in unstained preparations, e.g. *leptothrix* (Ford 1927), but the "pathologic significance of the organisms of bodily tissues was delayed, because of their smaller size, the difficulty of staining, and the prevalent misconceptions of pleomorphism" (Gay and Associates 1935).

The only available dyes were the vegetable ones, indigo and carmine, and not until more specific stains (chiefly the aniline dyes) had been developed could the true picture of the microorganisms be known. Sternberg and Pasteur demonstrated the diplococcus of pneumonia in the blood of rabbits inoculated with human saliva (1880). Telemon (1883), Frankel (1885), and Weichselbaum (1886) found them in the mouth and showed their relation to pneumonia (MacFarland 1915). It was not known at this time that the pneumococcus formed a heterogeneous group of many types. *Friedlander's bacillus,* occasionally encountered in the normal saliva and often present in cases of pneumonia, was originally considered to be the etiological agent of the disease. It was first described in 1883-(MacFarland). Ford considered the organism to be rarely present in normal mouths. The diphtheria bacillus was isolated and cultivated in 1883 and 1884 by Klebs and Loeffler. The organism was grown on a special blood serum developed by Loeffler. Plaut (1894) and Vincent (1896) first associated the spirochetes they found in the mouth around the teeth with the fusiform bacilli. They are usually associated with cases of ulcerative stomatitis, but some may be present in apparently healthy mouths.

Toward the end of the nineteenth century W. D. Miller established a landmark in this field with his publication of The Micro-organisms of the Human Mouth (1890). Most of the book is a record of his own observations, and in it he described the part played by the mouth and its constituents under normal and abnormal circumstances, discussed the properties of saliva, and formulated a chemical-parasitic theory to explain dental caries. The names and descriptions of the organisms which Miller found in the mouth have been the foundations of the later investigations in the field. In some cases the nomenclature has been modified to correspond to the more advanced knowledge of the microorganisms. It was believed that when all the microorganisms had been isolated and cultivated the mystery of disease would be settled, but a new field of work was begun when some of the organisms of disease were found to pass through filters. This was the beginning of research on the ulra-microscopic viruses.

At the close of the nineteenth century numerous bacteriological discoveries were being made including the organisms of the normal mouth and the causative agents of respiratory diseases. During the first three decades of the twentieth century, very few new organisms were discovered, but there was a correlation of the findings of independent investigations and a more complete description of the organisms was possible after pure cultures were isolated. These were necessary to establish the existence of the specific pathogens for each disease. In earlier times they had only been accidentally obtained. More attention was devoted to normal body organisms as well as those concerned with disease.

Around 1900 Lehman and Neuman wrote an Atlas and text on bacteriology, in which they described two organisms of healthy mouths, Streptococcus pyogenes, and Micrococcus tetragenus, and one found often in the saliva, Streptococcus lanceolatus.

Goadby in 1903 published "Mycology of the Mouth". He used the term "mycology" since the flora of the mouth included organisms other than bacteria, and he considered it to be a general term for all of them. He believed the environment played the greatest role in determining the flora of the mouth. In experiments on various mouth organisms he found that the majority produced an alkaline reaction in the absence of carbohydrates, and that a number of them were able to ferment carbohydrates with the production of acid. Miller's observations on the microorganisms of the mouth were repeated by Goadby and accurate descriptions of them were given. Dental caries was an important problem then as it still is today and twelve types of organisms were described in connection with decay. Streptococcus brevis, Sarcina lutes, and Bacillus necrodentalis are examples of these.

Until 1903, when Schottmüller demonstrated their action on blood agar plates, the virulent strains of streptococci could not be distinguished from the harmless forms. Both were often found in the mouth. The ability of the pathogenic forms to hemolyze the red blood cells is still used today as the means of differentiating them (Gay and Associates 1939).

Andrews (1906) in studying the flora of the buccal cavity found streptococci to be the organisms most frequently encountered. He did not

attempt to differentiate them but gave them the general name of Streptococcus salivarius.

During 1903 and 1904 the association of the fusiform bacillus with the spirochetes around the teeth of many individuals, some of whom showed little evidence of disease, received much attention from the bacteriologists. The nature and significance of the organisms is still disputed today, but in 1923, Ruth Tunnicliff considered them as different phases of the same organism and presented very good evidence for her theory. Many who followed her have adopted her viewpoint and research on the subject is still in progress.

Elser and Huntoon (1909) occasionally found Gram negative chromogens in the normal mouth.

Pneumococci of a low virulence were found by Zinsser (1922) in thirty percent of all the cases tested, while the virulent types were demonstrated in convalescents and temporary carriers, and were not found as often (Ford 1939).

Early in the century the anaerobic forms received relatively little attention. In 1923 Holman and Krock found and described small filter-passing cocci and bacilli-(Ford 1939).

An excellent piece of work was done by Noguchi on the spirochetes (Jordan and Falk 1928). He found more of the organisms in unclean or diseased mouths but did not correlate them with diseases. Examples of these mouth spirochetes include large, medium, and small types, of which the larger are the common Treponema buccale, and Borrelia vincenti, while the smaller include the Treponema dentium of Hoffman and the Treponema microdentium.

Davis (1928) considered the large number of microorganisms in the mouth to be dependent on the presence of the teeth because of the spirochetes and the fusiform bacilli around them which are always in evidence after the teeth have erupted and diminish when the teeth disappear in old age.

The causative agent of Thrush, now called Oidium albicans, was discovered in 1839 by Langenbeck and Berg. In 1929 it was considered by Benham to be an inclusive species, embracing besides the Thrush organism, the organism of Sprue, and several types taken from skin lesions. (Zinsser and Bayne-Jones 1935). The species of Monilia have been differentiated by agglutination methods.

In 1931 Goadby published his second edition of Diseases of the Gums and Oral Mucous Membranes which brought up to date the classification of all the known organisms and the theories of dental caries. MacNevin and Vaughan in 1933 completed their review of the literature from ancient times to 1930. The chapter devoted to "The Normal Mouth" was a necessary part of their book, Mouth Infection and Relation to Systemic Disease. These works conclude the historical aspect of the problem.

III - NORMAL FLORA OF THE HUMAN MOUTH.

The mouth is the portal for the entrance of the microorganisms of the environment into the alimentary tract. Those present in food and drink are immediately swallowed, and are acted upon by the digestive juices, while those entering in dust or droplets remain on the mucous membranes of the mouth. Unless those introduced organisms are able to invade the tissues, or to form colonies, their stay in the mouth is very brief. In 1922 an experiment was performed by Bloomfield in which carbon particles were introduced into the mouth and their action observed. He noticed very little tendency of the particles to become dispersed throughout the mouth. They were removed directly backwards, and by the end of a half hour most of them had disappeared. This ability of the mouth to eliminate foreign organisms has been attributed to the suction power of the structures in the mouth and to the action of the saliva (Topley and Wilson 1936). A similar experiment using Sarcina lutea, a common inhabitant of the environment, gave the same results. The flora of the mouth is not appreciably altered by the chance introduction of microorganisms, therefore, but once they have colonized on the membranes they become part of the local flora and cannot be removed by any simple mechanical means, or probably by the usual disinfectants. As early as 1683 it was shown by Leeuwenhoek that only the superficial organisms were removed when the mouth was washed with vinegar.

The normal flora is composed of those microorganisms "somewhat

better able to resist the defensive mechanisms of the host, but at the same time unable (except when resistance is reduced to a low level) to invade the body tissues." (Jordon and Burrows 1945).

A. TYPES OF ORGANISMS FOUND IN THE NEWBORN INFANT

At birth the entire alimentary tract is sterile, and some (Kostecka, Gundell, and Schwarz) believe the mouth to be sterile also. Others, however, support the findings of Witkowski (1935) that a definite correlation exists between the microorganisms in the mouth of the infant and in the vagina of the mother. These are chiefly aciduric organisms, (Jordan and Burrows 1945) of which the Döderlein's bacillus, a member of the lactobacillus group, is the most conspicuous. Others present in varying amounts are Staphylococcus albus, coliform bacilli, and streptococci (Witkowski). Gradually other organisms establish themselves on the mucous membranes, and after a few days a variety of organisms are present which correspond to the mouth organisms of the mother and others in the environment. Pneumococci are the most numerous and in order of decreasing frequency appear hemolytic staphylococci, various types of streptococci, Friedlander's bacilli, corynebacteria (diphtheria-like organisms), sarcinae and Gram negative cocci (Witkowski). Wagner (1934) in experiments on new born infants found streptococci in seventy-five percent of the cases. After this period those organisms which are adaptable to the conditions in the mouth remain as its flora.

B. TYPES OF ORGANISMS FOUND IN THE MOUTH AFTER THE NEO-NATAL PERIOD.

The microorganisms which have been recovered from the mouth of the adult include all the known forms and of these a variable number have

been considered by various authors to constitute the normal flora. The earliest observations, of a complete nature, were made by Miller in 1890 on the microorganisms in the mouth. In every mouth he examined six organisms were present which he considered to be the permanent flora: 1. Leptothrix innominata, 2. Leptothrix buccalis maxima, 3. Bacillus buccalis maximus, 4. Spirillum sputigenum, 5. Iodococcus vaginatus, 6. Spirochaeta dentium.

These he was unable to cultivate on ordinary media, and their names were suggested by their habitat in the mouth, e.g. Spirochaeta dentium, a spiral organism commonly found around the teeth. Almost the same conclusions were reached by Vincentini in 1897 (MacFarland 1915) who described these and fifty-two other species, some of which were harmless, and others pathogenic.

The methods of classifying the microorganisms, as well as all plants and animals, have undergone gradual, but marked changes since the early days of bacterial taxonomy.

Since Miller's time the classification has become much more complex and many of the names he gave to the oragnisms are now obsolete. The original lists of microorganisms of the mouth have been renamed and expanded to include many other forms.

In the mouth the types of organisms commonly found are representative of many families based on Bergey's classification. The Lactobacteriaceae, including the genus Lactobacillus, which produces only traces of by-products other than lactic acid, and the genus Streptococcus, the species of which have been divided on the basis of their reaction on blood agar by the digestion of the red blood cells.

In the family Mycobacteriaceae are found the diphtheria bacillus, and the diphtheria-like organisms, the diphtheroids, which are non-pathogenic.

The common bacilli of the respiratory tract, *Klebsiella pneumoniae*, and of the digestive tract, *Bacterium coli commune*, are in the family Enterobacteriaceae. The family Micrococcaceae contains the chromogenic cocci, *Staphylococcus albus*, which produces a white pigment, and *Staphylococcus aureus* which forms a yellowish pigment.

These organisms which are protozoan-like in some characteristics form the order Spirochaetales, and the mouth forms are in the family Spirochaetaceae. These are spiral forms which compromise two genera, Borrelia, and Treponema.

Other rod shaped forms are in the families Bacillaceae (the fusiform bacillus) and Bacteriaceae (the organism *Bacteroides melaninogenicus*.) Rods or unbranched filaments are characteristic of the higher bacteria found in the Actinomycetaceae, of which the common mouth forms are in the genus Leptotrichia. Also found in many normal mouths are the yeasts. They may have the effect of a laxative and do have some vitamin content, but no other conclusive evidence of their affect on the individual has been found.

Common in the mouth around the teeth are the Endamoeba. Since they feed on bacteria they are usually regarded as harmless. *Endamoeba gingivalis* is the only species usually present.

C. DISTRIBUTION OF NORMAL ORGANISMS IN THE MOUTH.

Compared with the enormous numbers of bacteria which enter the mouth from the environment, relatively few are permanent inhabitants. Three factors in the mouth are responsible for this condition. First, the constant secretion of the saliva washes away the organisms in a short

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time; second, there is an excellent supply of blood to the mucous membranes; and finally the bacteria are drawn back toward the throat by the efficient suction mechanism of the buccal cavity. Smears from the mouth reveal that many of the organisms have a wide distribution, while others are typical for a certain location. The dorsum of the tongue is considered to be the most heavily contaminated area, but the saliva contains the best variety of organisms which it acquires from the regions it bathes. The lining epithelium of the cheeks always contains many staphylococci, often many rods, and occasionally spirilla. Around the teeth and gums spirochetes, and yeasts can often be demonstrated.

The numbers of bacteria present in the mouth have been studied quantitatively by plate methods and by direct counts with fresh saliva. Because of the varied requirements of the different types of bacteria, estimations made by the plate method were unsatisfactory. Richert and Crowley (1935) introduced a direct count method which differed from others in the use of an atomizer to break up the large masses of bacteria. These counts are useful in following the progress of pathogenic conditions, and to estimate the effect of antiseptics and of diet on the condition of the mouth.

1. The Saliva and its Microorganisms.

The saliva, a colorless, odorless, slightly viscid liquid, is secreted by the salivary glands at the rate of fifteen hundred cc. per day. "Microscopically it contains a few squamous epithelial cells, a few 'salivary corpuscles", chiefly mono-nuclear blood corpuscles, generally much swollen, and many miscellaneous bacteria." (Todd and Sanford 1943). The number of organisms present in the saliva is dependent on the condition

of the teeth and gums. The saliva provides the necessary moisture for the growth of the bacteria, but it is not a good culture medium for them since it has a slight bactericidal effect. Its inhibitory action is greater against those which are chance inhabitants than against those organisms which are normally present (Bibby and Ball 1937).

An experiment on the inhibiting powers of unfiltered saliva was performed by Clough (1934). The saliva inhibited the growth of common bacteria, e.g., Staphylococcus albus and Escherichia coli in an area of 2.5 cm. and inhibited the growth of Lactobacillus acidophilus from a 0.5 mm. to a six to eight mm. zone in forty out of forty-one cases on Kulp's tomato juice agar.

The contamination of wounds by human saliva has been observed and recorded since the time of Aristotle and Galen, but since then it has been demonstrated that it is the organisms present, rather than the saliva itself, which causes infections--(Miller 1890). By inoculating laboratory animals with saliva many organisms of disease have been discovered. This was the method used by Pasteur to observe the diplococcus of pneumonia for the first time.

The Hydrogen-ion concentration of saliva has been considered as a factor in dental caries since the earliest times. In 636 A.D. the acidity of saliva, thought due to the spoilage of food, was believed to be injurious to the teeth. In the early days of systematic dental research, litmus was used to test the acidity of the saliva. In the latter half of the nineteenth century the acidity was measured by quantitative titrations. Today colorimeter determinations are used. Studies on "the pH of normal resting saliva" were published by Brawley (1935), and the variations with

age and sex were determined. There was no significant difference in the average value for male and female except in those over 50. The average for males was 6.76 and for females 6.73. The range of normal pH was from 5.6 to 7.6 in their 3405 test cases. In my observations the pH of saliva, determined with Nitrazine paper, was correlated with the presence of yeasts in the mouth, and with the number of teeth filled in the past 2 years. The average of pH of those in which yeasts were present was 6.4 and in those without yeasts it was 7.2 (Table 1) In those with an alkaline reaction there were fewer fillings, 5.4 on an average, as compared with an average of 6.3 in those with yeasts. (Table 11)

In most of the past investigations on the relation of the pH to dental caries, no standard values for the saliva have been defined. In 1936 the Columbia University Dental Caries Research Group concluded that there was no evidence that "saliva was a vehicle for action of physiologic factors on the teeth".

The normal microscopic organisms of the saliva include the common types of bacteria, cocci, bacilli, and spirilla; the higher bacteria, actinomycetes, spirochetes, diphtheroids and yeasts.

The cocci make up sixty percent of the mouth organisms according to Kliger (1915) while Hine and Bibby (1939) found the percentage ranged from forty-nine to fifty-five percent.

Appreciable numbers of these are always present in the saliva. The cocci are divided according to their method of reproduction into streptococci, staphylococci, diplococci, sarcinae, and tetrads.

In addition to all other organisms 10,000,000 to 100,000,000 streptococci per cc. are present in saliva (Bartels 1937). Todd and San-

ford (1943) frequently found streptococci in the saliva and Andrews (1906) noted them to be the bacteria most often found in the mouth. The streptococci, due to their action of blood agar have been separated into the alpha hemolytic or viridans type, the beta or true hemolytic organism and the gamma or non-hemolytic streptococci.

The Streptococcus viridans which produces a partial lysis of red blood cells is almost always present and therefore cannot cause the inflammatory processes often occurring in the mouth. (Zinsser & Bayne-Jones 1935)and Henrici (1934) believe it to be able to cause disease at times. Topley and Wilson (1936) observed either the viridans or an indifferent type always in the mouth.

Many authors have described a Streptococcus salivarius with a general distribution in the mouth but the species viridans and salivarius are considered synonymous by Bergey. The organism is a Gram positive diplococcus in which the long axis of the cell lies in the axis of the chain and no capsule has been demonstrated. It is usually aerobic but may be a facultative anaerobe.

The beta hemolytic streptoccus, which causes disease, is less frequently found. Tobler (1929) and Tomarkin (1929) believed the hemolytic type could produce the viridans type and that the process was reversible. Gundel (1931) considered the streptococci to be polymorphous. The possibility that mutations of the relatively constant hemolytic strains to viridans and the conversion of streptococcus to pneumococcus was seriously considered by Gay and Associates (1935). Rosenow (1914) claims to have produced all these changes but the conditions under which mutations occurred were not understood.

The Diplococcus pneumoniae (Weichselbaum) was found in thirty percent of those persons examined by Zinsser and Bayne-Jones (1935), and Group IV was most frequently found. Dochez and Avery considered this type produces only 9.8 percent of the cases of lobar pneumonia, but found it often in the normal mouth (Jordon and Burrows 1945). Other types are probably present in those who come in contact with the disease. Todd and Sanford (1943) frequently found types III and IV.

Pneumococci have been studied intensively in this century by Neufeld and Handel in Germany, and by Cole and Associates in New York. Gundel and Linden (1931) found group IV normally in the mouth and trachea. The diplococci may make up fifteen percent of the normal salivary organisms. They are difficult to cultivate directly from the saliva. The organisms have a peculiar lanceolate shape and are encapsulated. They are Gram positive, and although they may grow in the absence of oxygen, they are usually aerobic.

The staphylococci enter the mouth within a few hours after birth and remain as harmless saprophytes throughout life (Broderick 1930). According to Zinsser they can almost always be demonstrated. The Staphylococcus albus is the most frequently encountered but Staphylococcus aureus can often be found. Both were described by Rosenbach as aerobic, facultative, Gram positive organisms.

The Gram positive Micrococcus candicans, and Micrococcus tetragenus are frequently found in the normal mouth (Zinsser and Bayne-Jones 1939).

The Gram negative Micrococcus catarrhalis, sometimes present in the saliva, morphologically resembles the meningococcus, but can be

distinguished from it by cultural methods and by fermentation tests.

A common organism of the air, Sarcina lutea is often an inhabitant of the mouth and can be demonstrated in the saliva.

The rod shaped bacteria include the Escherichia coli, the diphtheria bacillus, diphtheroids, and Klebsiella pneumoniae, the so-called pneumobacillus. Fusiform bacilli may occasionally be demonstrated in the saliva of those with an appreciable supply of tartar around the teeth, and lactobacilli in those with varying degrees of dental caries. The Escherichia coli (Migula) or Bacterium coli commune as it is often called, was found by Gilbert and Choquet to be present in forty-five percent of the normal mouths tested. Topley and Wilson include it under the Gram negative organisms found in the mouth. In nature it is widely distributed and many investigators find it often in the normal mouth. In morphology it varies from almost coccoid forms to long rods which may or may not have motility. In motile forms the movement is accomplished by peritrichous flagella. It is an aerobic, facultative, gram negative, non-spore-forming organism.

In the same family, Enterobacteriaceae, are the pneumobacilli of Friedlander, which are called Klebsiella pneumoniae by Bergey. They are often found in the mouths and throats of persons suffering from pneumonia and were originally considered to be the etiological agent of the disease. In other inflammations of the respiratory tract they are also often present, as well as in the saliva of healthy persons. These bacteria are non-motile Gram negative, encapsulated rods with rounded ends.

Morphologically the organisms causing clincal diphtheria and the harmless pseudo-diphtheritic organisms are similar. Both can be

found in the normal saliva at times. The Klebs-Loeffler bacillus or Corynebacterium diphtheriae has been found in thirty-three percent of persons without symptons of the disease. Both the diphtheria organism and the diphtheroids are aerobic Gram positive non-motile, non-spore forming rods. They may be either curved or straight, may have a granular appearance and are clubbed shaped. Zinsser (1922) considered the diphtheroid usually present in the mouth to be Bacillus hofmannii, but others are not uncommon.

Occasionally from ordinary mouth smears a few spirilla can be demonstrated, but their number is small in comparison with the other organisms present.

The higher bacteria, actinomycetes, and spirochetes are sometimes found in the saliva; the actinomycetes have been obtained from the mucous membranes and from the tartar around the teeth, and the spirochetes from the region of the teeth.

Yeasts have been considered to be occasionally normal inhabitants of the mouth but no special significance has been attached to their presence. In my experiments with seventy-five students yeast were found in thirty-three percent. A second culture was taken after two months from eight of those which exhibited yeasts. Of these six again showed yeasts. Their possible significance will be discussed under dental caries.

2. The Microorganisms on the gums and around the teeth

Goadby (1931) defined the gums as follows: "The actual gum tissue may be taken as that portion of soft tissues surrounding the teeth and attached to the cementum of the teeth immediately below the margin of

the enamel above and the tip of the crest of the alveolar process below." The gum margin can not be clearly distinguished from the general mucous membranes. The gums have no protective sterilizing mechanism, as do most of the regions of the mouth until they are injured.

The region of the teeth and gums contains chiefly protozoan-like microorganisms such as the spirochaetaceae, amoebae; the mold-like or filamentous Actinomycetaceae; the bacteroids and fusiform bacilli.

On the surface of the gums the small Bacteroides melaninogenicum, Oliver and Wherry, a Gram negative anaerobic bacillus is a common inhabitant. This organism produces brown-black colonies on blood agar. The condition and the area of the gum margin determine the numbers of these bacteria present.

The hemolytic staphylococci and streptococci present on the gums in small numbers in most normal mouths, are increased in those with varying degrees of inflammation.

Bacillus fusiformis, an aerobic Gram positive spindle shaped rod with peritrichous flagella, occurs in the crevices of the gums, between the teeth and in the crypts of the tonsils. It is often associated with the spirochete of Vincent's infection, but may be present in the normal mouth.

Streptococci, chiefly of the viridans type were isolated by Tunnicliff and Hammond in 1937 from the pulp of intact teeth without any infection. They considered their presence of no significance.

Tartar or salivary calculus occurs around the teeth of a sufficient number of individuals, so that the condition is considered normal, (Goadby 1931). The tartar is formed either by precipitations from

the saliva or from "calcification of inflammatory exudates attached to the necks or roots of the teeth" (Thoma 1936). Rosebury (1944) considered that microorganisms played an important part in the deposition of the tartar around the teeth. He found Actinomyces israeli to be the filamentous organism most frequently present on the surface and in the depths of the tartar. The areas which are protected from cleaning are covered by a bacterial plaque usually composed of actinomyces, coccal, and bacillary forms, and leptotrichia (Jordan and Burrows). Miller (1890) found yeasts in the tartar as well as many spiral forms. Thoma (1936) considered fungi, yeast, and the microorganisms from the saliva to make up the bacterial plaque on the smooth surfaces of the teeth.

The spirochetes have claimed most of the attention of the bacteriologists because of their many forms, their possible relationship to each other and to disease. Leeuwenhoek first described them in the mouth, and the Spirochaeta buccalis was probably the one he found, since it is the largest discovered in this region (Dobell 1932). Miller in 1890 in his classifications included descriptions of the known spirochetes. Goadby suggested that some of Miller's thread-like organisms were portions of mycelia of yeasts. Investigators such as Burdon 1939 since that time have concluded that true yeasts never possess mycelia, so that the organisms were probably mold-like. Noguchi (1928) who investigated the mouth species succeeded in obtaining pure cultures of spirochetes. The existence of spirochetes in the mouth was not easily demonstrated by the earlier methods of staining. Later Giemsa's stain was used, and Tunnicliff's , a modification of the Gram stain. Today much of the work on spirochetes is accomplished by the dark field illumination of unstained fresh material.

In 1918 Dobell divided the spirochetes of the mouth into four classes. The first was the Spironema buccale, similar to the Spirillum sputigenum of Miller. The second Spirocheta refringes, which Noguchi considered similar to the first. The Spirocheta buccalis (Kolle 1917) formed the third class and was considered to be the specific organism of pyorrhea alveolaris. Vincent's spirochete was in the fourth class. Goadby (1931) thought all four were closely related and were possibly "morphological varieties of the same type".

The family Spirochaetaceae is divided into genera, Borrelia and Treponema. The Borrelia,Swellingrebel,are small parasitic spirals with three to five small waves. The important oral species is the vincentii (Blanchard), Bergey. It is commonly found in close association with the fusiform bacillus in cases of stomatitis, but it is also present in normal individuals not suffering from the infection.

Park and Williams in 1939 included in their list of non-pathogenic spirochetes Borrelia buccale Cohn, which has four to twelve irregular flat coils, and is commonly found in the normal mouth.

Borrelia refringens, sometimes in the mouth as a non-pathogen, is often associated with the Treponema pallidum in lesions. This organism has three to fifteen wide, flat spirals (Park and Williams).

The Treponema, Schaudinn, are parasitic and frequently pathogenic forms with spirilliform bodies. Two typical species are the macrodentium and the microdentium of Noguchi, which can be isolated from the normal oral cavity. They are both anaerobes with tapering extremities. The microdentium, the smallest of the mouth spirochetes is less than 0.25 microns in diameter in the central part, while the macrodentium is from

0.7 to 1.0 microns.

Park and Williams (1939) mentioned also a common spirochete intermediate between macrodentium and dentium, called Treponema mucosum. This was also described by Noguchi (1928)

The Treponema dentium, Koch, similar to the pallidum, has four to twelve spirals and has been demonstrated to have flagella. These are often in deposits along the gum margin.

Besides these, Topley and Wilson considered a Treponema intermedium (Dobell 1912) to be almost invariably present between the teeth and gums. Under their list of spirochetes is included two spirilla, one described by Vincent, and one by Miller (1890).

True protozoa, the amoebae, are present in varying amounts in normal individuals around the teeth and gums. The important species in this region is the gingivalis, which has not been found to be pathogenic.

In some normal mouths and especially in those with varying degrees of caries the Lactobacillus acidophilus is often found. Its chief product is lactic acid, and the organism grows in an acid medium in the mouth. The rod is of variable size, and is a Gram positive, microaerophilic, nonmotile organism.

The mold-like organisms are combined into the family Actinomycetaceae. These are rods or unbranched filaments which are parasites of the human mouth. Many of the investigators in the field have discovered them in the mouths of those with no evidences of disease, and in some cases they have been considered normal inhabitants. Lord and Emmons (1936) noted anaerobic actinomyces in the mouths and tonsils of those without mycoses. In 1937 Emmons isolated Actinomyces bovis from the oral cavity where it

was able to live as a saprophyte and become pathogenic under certain conditions. It differed from the saprophytes of the soil. Rosebury (1944) considered these organisms, intermediate between bacteria and fungi, to be naturally located in the mouth and throat.

Leptotrichia is the common genus in this group. The organisms are Gram positive when young and gradually become negative. The filaments may be straight or curved and break up into short thick rods which are often clubbed at one end. The Leptotrichia buccalis has been described by Robin as a long, slender, unbranched filament similar to the one found by Leeuwenhoek. The organism is non-motile, aerobic, and non-spore forming. Henrici (1934) found it to be non-pathogenic, while Rosebury considers it to have no known pathogenic or other significance. Besides being isolated from the tartar it has been described from general mouth smears, and has been found on the dorsum of the tongue. Kliger (1915) thought this organism, the lactobacillus, and a Cladothrix placoides to be the three that made up the flora of dental caries. Some of the leptotrichia can be cultivated, but others have resisted the attempts of the investigators. When the tartar around the teeth and gum margins, containing these organisms along with the spirochetes, streptococci and fusiform bacillus is removed the growth is evident again in a few days.

The monilia have been obtained from the mouth in non-pathogenic situations (Benham 1935) but some think they have a harmful effect on the individual. Henrici found the monilia to be parasites of the mucous membranes, and described the organism of the disease Thrush in the mouth. Today it is known as Oidium albicans and is usually found in persons with general weakened conditions. It chiefly attacks younger children.

IV. THE ROLE OF MOUTH ORGANISMS IN ABNORMAL CONDITIONS

In addition to those organisms commonly found in the mouth under normal conditions there are those which are able to enter and cause infection. Some of these attack the general mucous membranes, others the gums, the tonsils, and the teeth.

It is with caries of the teeth that dentists have been most concerned from their earliest investigations to the present day. Caries is so prevalent in our civilization that it seems almost inevitable. Experiments on caries-free and caries-active individuals have given no uniform results, so there is no agreement among the investigators as to its definite cause and cure. It is therefore believed by most that many factors, such as the microorganisms present, diet, the effect of the constituents of the saliva and the chemicals in food and drinking water, interact to produce the caries.

Inflammation of the mucous membranes of the mouth are commonly called stomatites. These infections include those caused by spirochetes, actinomyces, and the various kinds of bacteria. The spirochetes are those of Vincent's infection, which are found in close association with the fusiform bacilli. The pseudo-membrane produced in monilia infections is characteristic of infections caused by the actinomyces. The staphylococci and streptococci are usually of the hemolytic type.

The gums and their margins are most commonly invaded by the anaerobic spirochetes, _Fusiformis dentium_ and the pyogenic bacteria.

Tonsilitis is caused by a variety of organisms including the

pyogenic bacteria, streptococci, staphlyococci, and pneumococci. Chronically diseased tonsils are usually a focus of infection for the mouth and other regions of the body. Often secondary infections follow tonsilitis, and after a tonsilectomy individuals are sometimes more susceptible to infections of the lower respiratory tract.

Secondary respiratory infections often occur after attacks of pneumonia and streptococcus infections, and sometimes after diseases which have injured the mucous membranes.

A. DENTAL CARIES

The cause of dental caries has interested man for many centuries and when no causes could be ascribed, he conjectured them. In the fifth century B. C. Hippocrates believed it to be caused by "depraved juices". Worms were commonly thought to be the exciting cause until long after microorganisms had been discovered and their possibilities understood. From Arabic writings in 850 A. D. we find it was thought to be due to an acid moisture which attacked the teeth (Khalifali 1937). In 1503 an unknown German writer describes its cause as acid arising from food particles in the mouth.

1. Organisms Associated with Caries.

One of the first theories still in repute today was adopted by Miller around 1890, and was known as the chemical-parasitic theory. He attributed caries to three factors, the microorganisms present around the teeth, the attack of the teeth by acids, and the resistance displayed by the vital forces of the teeth. The microorganisms act in the

decalcification of the enamel. He produced artificial dental caries in intact teeth by allowing fermenting bacteria in an acid medium to attack them. In similar experiments on teeth in an alkaline medium no caries developed (Goadby 1931). Miller therefore supported the assumptions of Liber and Rottenstein (1861) that a mixed oral flora produced the acid necessary for the decalcification of the teeth(Thoma 1944). After his observations on the attack of the teeth were established, there were not many significant additions to his theory. Of the microorganisms which made up the oral flora Miller considered thirty-eight species to be pathogenic. Those of dental caries included B. necrodentalis, S. brevis, and B. subtilis. (Later investigators found B. necrodentalis very similar in cultural characteristics to Lactobacillus acidophilus.) Bud fungi were cultivated from the acid food particles present in dental caries and Miller thought them to be similar in function to osteoclasts.

The chemical-parasitic theory was advanced by Black (1886) and Williams (1889) and has been followed and enlarged upon by many investigators to the present day.

In 1915, Gies and Kliger undertook a study of the bacteriology of dental caries and found B. acidophilus and B. putrificus as well as Leptothrichia buccalis and cladothrix to be important in decay. Goadby (1899) demonstrated the active fermentation of carbohydrates in dentin by microorganisms, and isolated B. necrodentalis from the dentin. In 1931 Goadby described the successive stages in the process of decay; "first the decalcification and penetration of the enamel by organic acids produced from carbohydrates through the action of bacteria."

and second, "the digestion of the decalcified matrix".

In 1929, Jay found B. acidophilus to be present just before decay began. B. acidophilus, now called Lactobacillus acidophilus, can withstand an acidity of less than pH5.0 and can produce more acid in this medium.

B. acidophilus and a high carbohydrate diet were considered the important factors in dental caries by Bunting and his coworkers (1933). The enamel is dissolved by the action of the bacteria on the carbohydrates.

Enright, Friesell, and Trescher (1932) described the lactobacillus as a Gram positive rod which grows as a smooth colony and produces acid but not gas from common sugars.

Many investigators have found the organism in those without the disease and doubt its relation to the disease. Johnston, Kaake and Agnew (1933) claimed there was no close association between the acidophilus count and the amount of dental caries.

Henrici (1934) found a species of lactobacillus in the mouth which was able to produce the lactic acid that "dissolved the lime salts of the dentin and the enamel."

Burdon (1939) outlined the prevalent idea of acid formation by microorganisms in the food particles around the teeth.

Park and Williams (1939) thought Lactobacillus odontolyticus of the acidophilus group to be active in caries of the enamel, while less active forms could injure the dentin.

Arnim (1937) summing up the concept of caries, found the accumulated mass of evidence to point to the association of caries with the acids formed by the bacteria and other microorganisms present on the surface of the teeth. He also thought that their presence and effectiveness

were affected by dietary changes.

The appearance of bacterial plaques on the surface of the teeth are usually believed to be the forerunners of caries. The plaques are composed of organic debris and a large number of the filamentous Leptothrix buccalis (Thoma 1944). Here the acid producing organisms are found and the entire area is shown to have a low pH.

In 1943 the activity of caries by the production of acids in the saliva was tested (Hine and Wach, Kesel, O'Donnell). In the plaque material around the teeth of caries active individuals cocco-bacilli forms were found in great numbers while a mixed flora was found in the caries immune group.

In contrast to these and older views of plaque formation to explain the initiation of the caries, Beust (1936) concluded that "interproximal caries of enamel begins, in practically all cases at the actual point of contact of a tooth with its neighbor. Presence of an acid secreting plaque or colony at this point is environmentally and mechanically impossible."

Other authors found caries began in areas not frequently cleaned, where the bacteria and other microorganisms would have opportunity to multiply and the organic debris to become well established (Jordan and Burrows 1945; Arnim 1937).

Gottlieb and Applebaum (1945) believed two groups of organisms responsible for tooth decay, the aciduric and the proteolytic. The products from the aciduric are formed at the points of contact between the enamel and the dentin. The acid produced undermines the enamel which is not itself a favorable place for the development of the organisms. The

proteolytics form necrotic cavities in the dentin.

In 1936 Thoma described the "primary caries of pits and fissures". In these he considered the acidophilus bacillus to produce the acid which decalcified the enamel. As the decay passes into the dentin the aciduric bacilli are outnumbered by the proteolytic bacteria. The plaques on the smooth surfaces he found to be composed of fungi, yeasts, and mucin of the saliva.

Since most investigators have described the acidophilus organisms in dental caries a large amount of experimental work has been done on these forms. A bacteriophage method has been sought for the lactobacillus to control its presence in the mouth. Ulicny (1936) tried to find one but could not. He attributed his failure to "the high acidity of the medium necessary for the growth of these organisms". If the acidity could be reduced to the neutral point he thought a "phage" could be produced.

2. EFFECT OF DIET ON CARIES

It has long been known that those races that are primarily carnivorous have a very low incidence of caries. Many experiments have been performed by dentists and other research workers on the effect of carbohydrates, vitamins, calcium, fluorine, and phosphorous on the degree of dental decay.

Collins, Jensen and Becks, (1942) investigated the degree of correlation between a high sugar intake and caries. They tested college students from approximately the same environment and found that those with a high sugar intake had correspondingly high Lactobacillus acidophilus counts and a large amount of caries.

Most authors have found a high degree of correlation in similar experiments on other groups. An investigation on the incidence of caries in monkeys was conducted by Shaw, Elvehjem, and Phillips (1945) which revealed the condition to be similar to that in man and showed the possibilities for further investigations. They found diets with a high percentage of sucrose gave rise to frequent caries.

Bunting (1932) and innumerable other investigators have found carbohydrates to be a contributing cause of caries. They often provide the chief food for the acid-producing bacteria.

The effect of vitamins on the incidence of caries in the teeth of rats was studied by Agnew and Agnew (1933). Those given diets low in vitamin D showed lesions, while caries was absent in the control group.

Fosdick (1946) found synthetic vitamin K helped to decrease the acidity produced by the microorganisms of the mouth. With the acids thus weakened caries is less likely to develop.

3. Effect of Chemical Agents on Caries.

The presence or absence of fluorine in relation to tooth decay has received considerable attention in the last few years. Bibby in 1945 found topical applications of fluorine to arrest decay in young people, while Arnold (1945) found help from fluorine only during the formation period of the teeth.

Jay (1946) found in studying residents from fluorine areas (that is, areas in which the water supply naturally contains the fluorine) and who had lived there during the formative years, that their teeth contained more fluorine and that the lactobacilli were not able to flourish

in the mouths. This element is an enzyme-inhibitor and in test tube experiments prevents the growth and acid production of the bacteria.

The amounts of calcium and phosphorous present in human enamel are uniform, since the calcium-phosphorous ratio is not affected by the age or state of the teeth. The tri-calcium phosphate of the enamel is soluble in lactic acid and in other acids like it.

Klein (1932) and Agnew and Agnew (1933) in experiments on rats which were fed low phosphorous diets, found that this regime favored the production of caries-like lesions. However, Shelling (1933) thought the lesions were due to physical injury, and also believed the correlation between the lesions of the rats and of humans was not well established. (Arnim 1937)

Some persons naturally immune to dental caries can be shown to possess ammonia nitrogen in their oral cavities. When produced in small amounts in the mouth" it may be effective in preventing the decalcification of the tooth substance". (Kesel, O'Donnell, Kirch, and Wach 1946). Kesel found the ammonia to inhibit the growth of lactobacilli. A mouth wash and tooth paste containing these elements showed a reduction in the acidophilus count in contrast to the control group. He and his associates believe that if the experiment is carried on over a longer period of time a reduction in caries may result.

4. The acidity of Saliva and Carious lesions.

Jordan and Burrows (1945) found the region around carious lesions to have a pH of 5.0 or less. The acidity was tested on bacterial plaques after glucose rinses. The acidity of caries areas was investigated

also by Stephan and Zoller (1945) in teeth in situ and vitro. In situ, the average pH was 4.77. In vitro, 4.82 was the average; while the range in both was from 4.4 to 5.3. The experiments "indicated that the acidity of relatively inaccessible carious lesions is maintained for a longer time than the acidity of more accessible lesions and plaques."(Stephan and Zoller 1945). In my observations on a group of students those with a slightly higher number of fillings had a slightly lower pH of saliva.

The variation of dental plaques in caries-active and caries-immune areas was determined by an antimony electrodes. Those in caries-active areas exhibited a lower pH (Stephan 1943).

Since the pH of the saliva in the area of caries is lowered by the acid produced by the microorganisms acting on carbohydrates, alkaline buffers for the saliva have been suggested to neutralize this action.

B. Stomatites

Inflammations of the oral cavity, often called stomatites, are caused by a variety of microorganisms. The spirochetes and the fusiform bacilli of Vincent's infection have perhaps received more recognition than any of the others. Streptococci,especially of the viridans and hemolytic types; staphylococci, both aureus and albus; and pyogenic bacteria have been found often in the infectious oral diseases. The offensive odor from most of these infections is characteristic, and is often the outstanding symptom of Vincent's disease.

1. Vincent's Infection

Vincent's angina, popularly known as trench mouth, produces

lesions in the mucous membrane beginning in the areas around the teeth, and causes varying degrees of necrosis. As the necrosis proceeds the characteristic odor develops, severe pain and a general weakened condition follows. (Prinz 1935) Predisposing factors include a state of lowered resistance, neglect of oral hygiene, and infected teeth.

A history of the disease begins in the era before Christ but a record of the organisms appears with the nineteenth century. Veillon and Plaut mention the presence of the fusiform bacillus and the spirochetes but not as related to disease.(1894) Vincent in 1896 associated the bacillus with "hospital gangrene" and inflammations of the pharynx, and recorded that spirochetes were present. By 1905 the association of both of these organisms with disease had been made and accurate descriptions of them were published. After Schaudinn (1905) described the spirochete of syphilis all spirochetes received a great deal of attention and efforts were made to understand them better by cultivation. Hampp (1945) was able to do this on veal heart hormone agar. In this way the spirochetes present in Vincent's infection became an important organism of the mouth cavity (Hampp 1945).

The organisms frequently associated with the infection are sometimes considered to be present in normal mouths around the gum margin and in the tonsillar crypts (Burdon 1939). When the disease is present the spirochetes are the predominating organisms and are found in advance of the fusiform bacilli in the lesions. They also penetrate first into the tissues that are later destroyed. Their presence in these conditions is considered to be of possible etiological significance.

Isolation and cultivation of the fusiform bacillus, has been possible for a long time, but the spirochetes have been more resistant to cultivation (Hampp 1945). An attempt at their isolation and cultivation was made by Hampp on spirochetes associated with the ulcero-membranous condition in the mouth. The spirochetes he considered to be a mixture of species. On veal heart hormone agar he dug a well to receive the organisms which had first been identified by dark field illumination. The well prevented the contaminating organisms from spreading and allowed only the spirochetes to penetrate the media. At the end of twenty-four hours spirochetal growth was evident on the primary plates "rendered anaerobic with hydrogen". By modifications of this technique two other strains morhologically similar to the Borrelia vincenti commonly described were isolated. Their results show the unreliability of stained smears to determine the oral spirochetal species. No conclusive evidence has established the Borrelia as the etiologic agent of Vincent's infection.

Wilbur in 1946 found at least two other organisms which he considered necessary for the production of the disease. One of these is a vibrio and the other a streptococcus and both are strict anaerobes. He also suggests the possibility of mistaking other spirilla for the Borrelia vincenti which may not be the normal organisms they are usually believed to be. The likeness of the disease to one caused in the mouth by a virus suggests the possibility that a virus may also prepare the tissues for the infection. The known virus-caused disease is called infectious gingivostomatitis. The vesicles have been shown conclusively to contain the herpes simplex virus. The vesicles formed serve to distinguish it

from Vincent's. Ordinarily Vincent's disease is believed not to be communicable but under congested conditions it seems to spread quite readily, as is evidenced by its widespread appearance in armies. If the infection is caused by spirochetes which are not cultivable, the possibility of its spread by eating utensils and other contaminated articles does not seem possible. Intimate contact is a more likely way of spreading the infection.

Whir (1946) believes further investigation on the entire oral flora is necessary before the symbiotic spirochete and fusiform bacillus can be regarded as the etiological agents of Vincent's infection. He considers oral hygiene to be the principle factor in its cure. The bacterial smear, made to discern the presence of the organisms is often positive after the clinical symptons have disappeared. Many mouth washes and antiseptics have been prescribed to eliminate the condition, and the antibiotic, penicillin, which has been used for a variety of diseases and tried on many more, has been suggested. Naegeli and Morginson (1945) found penicillin useful in clearing up the infection. Burdon (1939) believed salvarsan to be effective against these spirochetes, as against those of syphilis.

Before this infection, known for such a long time, can be fully understood and cured or prevented, more research is needed. This is the universal conclusion of investigators in the field, whether or not they ascribe the disease to the action of the Fusiformis dentium and the Borrelia vincenti.

2. Other Stomatites

The bacteria constantly present on the gums are a source of

infection to them and to the other membranes when injuries occur on them. In membranous stomatitis almost any part of the mouth may be affected, and on these surfaces Streptococcus viridans and staphylococci may be present. The infection is a mixed pyogenic one (Thoma 1936).

Noma, or gangrenous stomatitis, may be caused by the anaerobic organisms of Vincent's infection, the spirochetes and fusiform bacilli, or it may be caused by the hemolytic streptococci. Trauma may also be an exciting cause. It often occurs when the tissues have reduced vigor due to a primary infection.

In some cases where abrasion of the mucous membranes has occurred, gonococci may invade the tissues. Ordinarily it is an infection of the new-born.

In the mouths of young children the entire oral mucosa may be infected by streptococci or staphylococci, the latter usually of the citreus type. The areas may be inflamed and many small ulcers formed. This condition is spoken of as aphthous stomatiis Thoma 1936).

Inflammation of the paradontal structures (Thoma 1936) is usually superficial and resembles paradontal pyorrhea. The infection by the bacteria in both is generally secondary. In cultural examination a variety of organisms have been isolated including spirochetes, spirilla, different types of streptococci, staphylococci of the albus and aureus forms, pneumococci, streptobacilli, streptothrix and yeasts. Vincent's infection may invade the diseased tissues. "The bacteria grow on the ulcerating gingiva and penetrate into the tissue, the periodontal membrane, and the bone." (Thoma 1936).

Goadby (1931) describes catarrhal gingivitis as a simple inflammation from which a variety of organisms have been isolated, including the Micrococcus catarrhalis, pneumococci, and certain streptococci. Of these the first two are the most common. He noted a relationship between the bacteria of this infection and the organisms which are first isolated from pyorrhea.

Chronic gingivitis (Goadby 1931) is an inflammation of a more serious nature and is characterized by scarlet gums. In this condition he also found a variety of organisms, chiefly Gram negative rods which were morphologically distinguishable from B. fusiformis. Spirochetes are often found but aside from these no constant bacterial types have been observed.

3. Actinomycosis

The disease of the gums caused by actinomycetes, Goadby considers to be mycotic gingivitis. However the infection usually spreads to other parts ofthe oral cavity and causes a general infection of the mucous membranes. The organisms are anaerobic parasites. Actinomyces bovis was reported from the normal mouth by Emmons (1936). It is capable of producing lesions of the mucous membranes when these tissues are weakened. This probably occurs after a primary infection or after the tissues have lost their "immunity mechanism" (Jacobson 1932). Rosebury (1941) described the Actinomyces israeli as a strict parasite which forms a mycelium and whose natural habitat seems to be the mouth and throat. It has the power to cause actinomycosis under abnormal conditions. In preparations from the mouth, clubs are seen and branched filaments can be observed. Topley and Wilson (1936) thought this organism could survive

for a short time in artificial media and for this reason could be transmitted by oral or nasal secretions, chiefly infected saliva or pus.

The Oidium albicans, often referred to in the earlier literature as Monilia albicans, is the causative agent of thrush. It is a yeast-like fungus which reproduces by budding, and produces a mycelium. The oral mucous membranes, surfaces of the cheeks, tongue, lips and gums, are usually attacked. A pseudomembrane is formed of diffuse material which is most often whitish. In young cultures mycelia are usually absent, and if present there are very few filaments. They may be present in older cultures (Jacobson 1932). Lewis (1939) thought the oidium organism was a common inhabitant of the gastrointestinal tract. It is sometimes found in poorly nourished children, or in infants in hospital wards where it probably spreads by contact with infected equipment. Otherwise it is not usually very contagious. The appearance of the organism in cultures is very characteristic. Yeast morphology is observed on solid media and mycelia can be observed in liquid. Burdon (1939) described its growth on solid agar in which mycelial threads develop below the surface. The filaments are made up of massed elongated threads which develop clusters of blastospores at the ends.

Besides these infections of the oral cavity produced by microscopic organisms, there are also inflammations and lesions in the mouth which are manifestations of systemic diseases. These diseases include measles, scarlet fever, diphtheria, which forms a greyish white plaque, typhoid, which forms shallow ulcers, and secondary or tertiary manifestations of syphilis.

C. Secondary Respiratory Infections

All secondary infections are caused by the "implantation of one or more varieties of microorganisms upon an existing infection" (Park and Williams 1939). This is a common occurrence in the respiratory tract and the diseases caused are often mixed infections. Often infections due to filtrable viruses aid in the invasion of bacteria (Park and Williams 1939). Also in secondary infections the effect of the different microorganisms on each other is sometimes important, since some are able to live in symbiosis.

The commonest virus respiratory infection is the cold in which no one type of bacterium is characteristic in the early stages. The bacteria which are always present have a chance to infect the area when it has been weakened. During the later stages of the cold, virulent organisms may be present, such as hemolytic streptococci, and staphylococci. These and the organisms of pneumonia, diphtheria, and meningitis may cause secondary infections which may be far more serious than the original infection.

Diphtheria which has been traced back to the time of the ancient Greeks under a variety of titles, paves the way for secondary infections. Bronchial pneumonia may follow laryngeal diphtheria, and scarlet fever may occur as a complication of diphtheria.

Lesions of tuberculosis in the mouth are generally secondary to pulmonary tuberculosis (Thomas 1936). The sputum is the vehicle which brings the organism in contact with abrasions in the mouth where it has the ability to form ulcers and then later nodules around these ulcers. In this case the same etiological agent is present while in the other examples the organisms with secondary invasive powers differed from those

of the primary infection.

D. The Teeth and Tonsils and their Role as Foci of Infection

The focus of infection is that area which contains the organisms of the disease and from which they spread to other parts of the body. The manner in which foci infect the body is not clearly understood. In some cases it is spread directly to adjacent tissues, in some the lymphatics are responsible for its dissemination, and in others the blood stream is able to carry the infection to diverse organs.

Infected teeth, which are neglected, are chronic sources of infection and to them have been ascribed pains of a general sort which have no known etiological significance. Rheumatic conditions have also been considered to be the result of focal infections.

Pyorrheal paradontitis is an important focus since almost all of the teeth are affected at the same time and there is a large amount of absorption of the infectious products by the circulation.

Sub-acute endocarditis is often attributed to the _Streptococcus viridans_ of dental infections. Most of these organisms which enter the blood stream are destroyed by it, but some which escape attack the endothelium of the heart valves.

The tonsil was considered a focus of infection in the late 19th century when its structure and functions were understood. In 1894 Wolfenden, in explaining the manner of infection, thought that the number of bacteria, especially streptococci, determined whether or not the infection was localized there, or would spread throughout the system. In 1936 Lebron found hemolytic staphylococci and streptococci predominated

in all tonsils examined. Gay and associates (1935) considered the hemolytic streptococci to be the causative agent of follicular tonsillitis and thought most other investigators were in agreement with them. Tonsillitis, which may itself be a secondary infection, leads to other diseases such as septic sore throat and the rheumatic state, in which no agreement has been reached regarding its bacteriology.

Nephritis often occurs in those with diseased tonsils and teeth, but this is not sufficient evidence to conclude their etiological relationship (Jordan and Falk 1928). The streptococci are the important organisms involved. Lyttle (1942) thought the Streptococcus hemolyticus found in nephritis originated in the respiratory tract. Once these organisms gain entrance to the kidney and become established, tonsillectomy is not effective in curing the nephritis. In 1939, Illingsworth concluded that tonsillectomy did not prevent or cure nephritis, but in some cases increased the infection.

Otitis has often been associated with tonsillitis and many attempts have been made to cure it by removing the tonsils believed to be the focus of the infection. Bass (1934) recorded the results of his cases of tonsillectomy with regard to otitis media. Out of forty cases, thirty-two complained of otitis before and did not have it following the operation; four had it before and after, while the remaining four contracted it afterwards although they had not previously suffered from it. Therefore, he, along with many others, felt the tonsillectomy helpful in curing otitis.

The incidences of diphtheria and the carrier rate with regard to tonsillectomies have received considerable attention from the Health

departments of many cities. In general, many investigators believe tonsillectomy lessens the danger of infection from this disease. Since the organism can establish itself in lymphoid tissue, the tonsil is often the first area to be infected.

After tonsillectomy and other oral surgical operations in which anaesthesia is used, diseases of the lungs may follow. These may be due to inhaling infected saliva sometimes containing Vincent's organisms, and infected blood (Thoma 1936).

Kaiser (1942) studied the effect of tonsillectomy on the respiratory system of children. He found no reduction in the number of lower respiratory infections, but rather that the presence of the tonsils was slightly beneficial in preventing them. In many cases the removal of tonsils and adenoids helped discourage upper respiratory infections which were already established.

Paton recorded the cases of nine hundred school girls in the period from 1930 to 1939. He, along with Glover and Wilson, (1932) believed that a large number of tonsillectomies were not useful and did not decrease the susceptibility to respiratory infections. He thought removal of the adenoids increased the susceptibility to middle ear infections.

In a critical appraisal of the whole idea of focal infection, which would include the belief that the tonsils affect so many diseases, especially the respiratory ones, Reiman and Havens outline what is known of the situation. They do not think the theory of focal infection has been proved. The infectious agents which are concerned with the various diseases are unknown, and often the improved health of the individual cures

the disease without removal of the so-called focus of infection. In regard to the tonsils and tonsillectomy as a remedy for all sorts of ailments they find surgery alone to be seldom helpful, since the same disease is often present with no reduction in virulence after the tonsils have been removed. In other cases those with tonsils removed have same susceptibility to respiratory infections as those who have had them removed.

V. THE OCCURRENCE OF YEASTS IN THE NORMAL MOUTH AND THEIR RELATION TO SALIVARY ACIDITY AND CARIES

The presence of yeasts in the normal mouth has been noted by many investigators including Miller (1890), Bunting (1933) and Thoma (1936). Most authors considered them to be harmless saprophytes and many have recommended them for therapeutic purposes. Henrici (1934) believed there was no scientific basis for prescribing them since their only value, except for their vitamin content, was as a laxative. Fosdick and Hansen (1936) experimented on yeasts in the mouth in relation to acid production and the dissolution of enamel. They found the fermentation action of the microorganisms of the mouth, including the yeasts, on the carbohydrates to be accomplished by products excreted by or contained in the organisms. They believed the action of the yeasts to be due to the enzyme zymase. In 1936 they suggested that the formation of acids in the mouth was similar to the chemical reactions that occurred in the muscle tissue during the breakdown of carbohydrates and in 1939 in a second paper they showed this to be true. In both cases the first step is the formation of a carbohydrate-phosphate by enzymes.

In experiments with saliva, from both caries-active and caries-free individuals, which was shaken with glucose and powdered enamel for a definite time, they succeeded in causing dissolution of the enamel. In these mixtures they found yeasts in large numbers. They tried the effect of different microorganisms in the mixture and found under these experimental conditions that the acidophilus bacillus caused no solution of enamel, while the yeasts dissolved the largest amount. When the yeasts were grown together with the Bacillus acidophilus large amounts of enamel were

were dissolved. This shows that when the two organisms are growing symbiotically in the mouth they probably have an effect on the production of dental caries. When sodium fluoride was present there was no solution of the enamel.

Since yeasts usually produce alcohol instead of the acid they produced in this instance, Fosdick and Hansen looked for a reason for this atypical reaction. In reviewing the literature they found that the prese ence of calcium salts in the saliva could produce abnormal fermentation by allowing the yeast to produce lactic acid from the pyruvic acid they thought was present in the saliva. An increase in the formation of lactic acid was evident when *Bacillus acidophilus* was grown in symbiosis with the yeasts. Apparently the process of decay is accomplished by many separate reactions and in some stages the yeast is the active organism while in others the acidophilus is important. The saliva normally contains calcium and phosphorus ions which are often precipitated out when sodium fluoride is present and then no solution of the enamel occurs.

In 1937 Fosdick and Hansen worked with Wessinger in testing the reductase activity of mouth organisms and found that yeastsand *Bacillus acidophilus* could reduce more pyruvic acid to lactic acid in the saliva than any of the other organisms tested such as *B. subtilis* and *S. lutea.*

EXPERIMENTAL METHODS AND RESULTS

In my observations on the cultures made from the mouths of students yeasts were found to be present in thirty-three percent of the cases. Cultures were made by swabbing the mouth, especially in the areas around the teeth and streaking on Sabouraud's agar plates. This medium was used since its high sugar content inhibited the growth of most bacteria. In cultures in which no yeasts were present, colonies of staphylococci

were the only organisms which were able to grow. The yeasts were usually e evident in twenty-four hour cultures and grew in smooth white colonies. Two samples showed a pink coloration of the colonies. Some cultures were later transferred to nutrient agar and exhibited the characteristic growth.

Microscopically the cells were oval or elliptical, Gram positive organisms which stained deeply when young. In older cultures the characteristic vacuoles were apparent. All of them reproduced by budding, without the formation of endospores. Park and Williams (1939) considered the buds to be blastospores. Mycelia did not develop on the Sabouraud's medium.

To determine the fermentation ability of the organisms they were inoculated into dextrose and lactose broth. In most cases gas was formed in dextrose and no case was it formed in lactose.

The acidity of the saliva was also tested in connection with the presence of yeasts. The range of pH in persons with yeast was from 5.0 to 8.0, while the average was 6.4. In those who did not have yeasts the pH ranged from 5.5 to 8.0 and the average was 7.2. (Refer to Tables I and II.)

The number of fillings in the past two years was noted and showed a low degree of correlation with the acidity of the saliva. This number, however, did not include all the "pin point" caries not filled by the dentist, so that the amount of carious activity is not accurately given by these figures. While 6.5 was the average number of fillings of those with yeasts, the 5.4 average of the others is not sufficiently lower to be

very significant. Nevertheless, the presence of yeasts in the more acid mouths, and the slightly higher incidence of fillings in those with yeasts indicate a trend in the same direction. It seems probable then that the yeasts, occurring in as many as thirty-three percent of normal mouths, may play some part in the production of acid and therefore of caries. The experiments of Fosdick and Hansen (1936, 1937, and 1939) show that this may be possible.

TABLE I

CULTURES WITH YEASTS

NO. OF CULTURE	pH OF SALIVA	NO. OF FILLINGS	NO. COLONIES PER PLATE
51	8	6	25
52	8	6	100
53	8	8	3
54	7.5	12	16
55	7.5	6	2
56	7.5	5	100
57	7.5	4	6
58	7	17	9
59	7	10	5
60	7	5	9
61	7	2	11
62	7	2	2
63	6.5	4	11
64	6.5	4	1
65	6.5	3	4
66	6.5	0	1
67	6	12	13
68	6	10	1
69	6	4	14
70	6	6	2
71	6	0	11
72	5.5	12	3
73	5	10	178
74	5	6	2
75	5	4	20

AVERAGE pH 6.4

AVERAGE FILLINGS 6.3

AVERAGE COLONIES 22
PER PLATE

TABLE II

CULTURES WITHOUT YEASTS

NO. OF CULTURE	pH OF SALIVA	NO. OF FILLINGS	NO. OF CULTURE	pH OF SALIVA	NO. OF FILLINGS
1	8	9	26	7.5	5
2	8	9	27	7.5	5
3	8	7	28	7	40
4	8	6	29	7	18
5	8	5	30	7	8
6	8	5	31	7	4
7	8	4	32	7	5
8	8	4	33	7	4
9	8	4	34	7	3
10	8	4	35	7	3
11	8	4	36	7	0
12	8	3	37	7	0
13	8	3	38	7	0
14	8	2	39	7	0
15	8	2	40	6.5	8
16	8	2	41	6.5	6
17	8	2	42	6.5	4
18	8	1	43	6	12
19	8	1	44	6	8
20	8	0	45	6	4
21	8	0	46	6	3
22	8	0	47	6	3
23	7.5	10	48	6	2
24	7.5	10	49	5.5	14
25	7.5	7	50	5.5	12

AVERAGE pH 7.2

AVERAGE FILLINGS 5.4

VI - SUMMARY AND CONCLUSIONS

The infections of the mouth have been described in the literature since ancient times. Gradually as methods of investigation improved, the true nature of these infections became apparent. Leeuwenhoek, 1682, was the first to describe the minute "animalcules" that are constant inhabitants of all mouths. After his time their association with disease was realized.

The microscopic flora includes all the organisms too small to be seen with the naked eye which inhabit the oral cavity of humans. The normal flora of the human mouth was shown to consist of many groups of organisms which varied considerably among individuals, and at different times in the same individual. Nevertheless, there were many which were present in all mouths and others whose frequency was sufficient for them to be considered normal.

The microorganisms which invade the mouth of the infant at birth and in the first few hours of life are chiefly the aciduric types of bacilli from the vagina of the mother. Next the organisms from the external environment enter and supplant these.

A short time after birth the number and kinds of organisms are greatly increased and include all types of bacteria; cocci, bacilli, and spirilla; filamentous forms such as actinomycetes, and leptotrichia; amoebae, yeasts and protozoan-like spirochetes. Some of these are distributed generally throughout the mouth on the mucous membranes. Others are found in certain areas such as around the teeth and gums. Most of them

can be demonstrated in the saliva which bathes all regions of the mouth. The condition of the mouth and teeth determines to a large extent the number and variety of organisms present.

Under abnormal conditions the microorganisms normally present in the mouth may attack the teeth, and cause lesions and inflammation in other parts of the mouth. The problem of the gradual decay of the teeth has been investigated for many centuries, but is still unsolved. The theories to explain its cause have been based on many factors. The most important are those which are concerned with the acid-producing microorganisms, since dental decay is accomplished by the dissolution of the calcium phosphate of the teeth by acids. These organisms are chiefly of the lactobacillus group which are frequently present in the normal mouth. Subordinate theories are concerned with the effect on dental caries of carbohydrates in the diet which furnish food for the microorganisms, vitamins in the diet, and the lack of mineral elements in the saliva. It seems probable that all these factors interact and that no factor is responsible for the condition.

Organisms normally present in the mouth are also involved in stomatites, such as Vincent's infection, ulcero-membranous stomatitis, and other less widespread types of stomatitis and gingivitis. The lesions are localized either on the lining of the cheeks, on the tongue, or around the teeth. The types of organisms present include the spirochetes and fusiform bacilli of Vincent's disease, which are also present in other inflammations; pyogenic bacteria, hemolytic streptococci and staphylococci, pneumococci, gonococci, and actinomycetes. Secondary respiratory infections such as bronchial pneumonia, often occur when mouth

organisms invade tissues impaired by a primary infection. These are frequent after the common cold, diphtheria, measles, and other common primary infections. Diseased teeth and tonsils have been considered as foci of infection for other parts of the body. Their manner of infection is obscure. The ailments ascribed to these foci are chiefly those for which no etiologic agents have been proven, although in many of the cases streptococci have been isolated. The infections include the rheumatic state, endocarditis of the sub-acute variety, nephritis, and otitis. The effect of tonsillectomies on these and respiratory infections has been considered.

The occurrence of yeasts in the normal mouth was discussed in relation to the acidity of the saliva and to dental caries. Fosdick and Hansen (1936) found that yeasts from the mouth were able to dissolve enamel when shaken with it for a number of hours. In my observations yeasts were found in thirty-three percent of the mouths examined and in most of these cases the pH of the saliva was slightly lower than in those without yeasts. It seems possible that the presence of yeasts in normal mouths may play some part in the production of acid and therefore of caries.

VII - ABSTRACT

Leeuwenhoek was the first to publish observations on the microorganisms found in the normal human mouths. Since then microorganisms have been recovered from all the body surfaces, openings, and the respiratory and alimentary tracts, but not from the tissues which are sterile from birth. A knowledge of the flora normally in the mouth is useful, since under certain conditions it may cause disease, or its products may exert a harmful effect on the body.

The Egyptians, in the Ebers Papyrus, were the first to write on diseases of the mouth which were found many centuries later to be caused by microorganisms. The process of tooth decay, then as now, was a serious problem. In the early days of their history the Chinese described infections of the teeth and gums but made no great contributions to scientific knowledge. Hippocrates first gave an explanation of focal infection.

With a crude microscope Leeuwenhoek examined particles from his own mouth, around the teeth, and from the mouths of others. He presented accurate pictures of the common types of bacteria he found in them.

As methods of observation, isolation, and cultivation of microorganisms improved, a variety of types of mouth organisms were discovered. Pasteur and Sternberg(1880) performed an experiment on animal inoculation with human saliva. The diplococcus of pneumonia was recovered from the blood of the rabbit inoculated.

In 1890 the publication of The Microorganisms of the Human Mouth by W. D. Miller brought up to date the knowledge of the flora of the

mouth and included many original experiments and theories. By the beginning of the twentieth century most of the organisms present in the mouth were known but an understanding of their reactions and classification was undertaken by independent investigators.

The normal flora of the mouth is composed of the microorganisms which are able to live symbiotically or commensally with the host. At birth aciduric bacilli from the mother's vagina enter the mouth of the infant and after the first few hours of life a variety or organisms gradually establish themselves on the mucous membranes. In the adult all types of microorganisms known have been recovered from the mouth. These include the bacteria, spirochetes, leptotrichia, yeasts and amoebae. These can usually be recovered from the saliva, which has a slight inhibitory action, especially against those organisms not usually found in the mouth. The bacterial constituents and the pH of the saliva deserve consideration in regard to dental decay. In the saliva, cocci are found in the greatest numbers, but bacilli, spirilla, and some forms of higher bacteria can usually be demonstrated. On the gums and around the teeth the protozoan-like spirochetes, the mold-like actinomycetes, fusiform bacilli, amoebae, and bacteroids are often found. Hemolytic streptococci and staphylococci may also invade the gums. The role of spirochetes in the mouth has been of the greatest concern to bacteriologists, since those found in apparently normal mouths resemble the causative agents of diseases such as Vincent's angina and syphilis.

In abnormal conditions the organisms normally present in the mouth are able to invade the tissues and cause disease. The teeth, gums, and mucous membranes in general may be affected by this invasion of

microorganisms. The teeth are susceptible to caries in almost all races that are not of the strictly carnivorous type. Theories regarding the cause of decay have been formulated by numerous investigators for many centuries, but no one theory has been wholly acceptable. The Worm Theory was most common during relatively recent centuries even after microorganisms had been discovered. Of the recent acceptable theories the chemical-parasitic one of Miller was the most widespread. This and other theories which attribute decay to the acid production of microorganisms are considered to be the most important, since it is the acid which decalcifies the enamel of the teeth and causes necrosis of the layers beneath the enamel. The organisms chiefly associated with this condition are of the acidophilus type and are common inhabitants in the normal mouth.

Many investigators believe that the caries activity proceeds under bacterial plaques formed around the teeth, while Beust, concluded that the caries began at the point of contact between adjacent teeth. A high carbohydrate intake is considered to play a secondary role in the production of caries. The effect of chemical agents has also been studied in relation to dental caries. The presence of fluorine in the drinking water of young children, and of ammonia nitrogen in the saliva seem to arrest caries activity. The amount of phosphorus was considered to be another factor.

In most investigations on the saliva of normal persons a lower pH occurs in caries-active areas.

The stomatites include all the inflammatory processes of the gums and oral mucous membranes. Of these Vincent's angina is the most widespread infection.. The Borrelia vincenti and the Fusiformis dentium

have been considered to be the etiologic agents although conclusive proof of their role in the disease has never been given. Other stomatites and gingivites are often caused by bacteria normally present in the mouth which have the ability to invade weakened tissues.

Secondary respiratory infections are commonly caused by normal mouth organisms and occur after the mouth has been injured from a primary infection. This condition is often observed in the latter stages of the common cold.

The teeth and the tonsils have been considered to be foci of infection for generalized bodily ailments and for diseases in other parts of the body when no etiologic agents have been found as in cases of nephritis and infections of the heart valves. The same type of organisms, streptococci, have been isolated in many cases and resemble those of the respiratory tract. The manner in which the foci act is obscure and once diseases such as nephritis are well-established tonsillectomy does not help the condition. It has been considered useful in arresting chronic infections of the upper respiratory tract.

Yeasts normally occur in the mouths of many individuals. In my observations they were present in thirty-three percent of the cases tested. They have been considered in relation to the acidity of the saliva and to dental caries. A slightly lower pH and a slightly higher incidence of caries has been observed in those persons in whom yeasts were found. Fosdick and Hansen found that yeasts, when mixed with powdered tooth enamel, glucose, and saliva were able to dissolve the enamel. It seems likely that yeasts may play a part in tooth decay, perhaps by increasing the production of acid in the mouth.

BIBLIOGRAPHY

Agnew and Agnew, 1933. Quoted by Arnim, 1937.

Allen, 1913. Quoted by Stuart, Knudson, and Arnold, 1935. J. Dent. Res., 15:41.

Anderson, M., 1943. Tonsillar diphtheria. Brit. Med. J.,2:104.

Arnim, S.S., 1937. Present day concept of caries based on clinical and experimental data and the most fruitful approach to prevention and control of the condition. Int. J. Orth.,23:1045

Arnold, F.A., 1945. Discussion of possibility of reducing dental caries by increasing fluorine ingestion. J. A. Coll. Dent.,12:61

Bartels, H.A., 1937. Indications for bacterial examinations of the mouth. Int. J. Orth.,23:1222.

------------, 1937. Significance of Yeast-like organisms in denture sore mouths. Int. J. Orth.,23.90.

Bass, M.H., 1934. Results of tonsillectomy in practice. Laryngoscope,44;780.

Becks, A.L. Jensen, and Millan, C.B., 1944. Rampant dental caries. J. A. Dent.A.,31:1189

Belding, D.L. and Marston, A.T., 1938. A textbook of Medical Bacteriology. D. Appleton-Century Co., New York.

Berg, and Fosdick, L.S., 1946. J.Dent. Res.,25:73.

Bergey, D.H., and others, 1939. Bergey's Manual of Determinative Bacteriology. William and Wilkins Co., Baltimore.

Beust, T.B., 1936. Contact-point caries. J. Dent. Res.,25.453.

Bibby, B.G., 1944. Use of fluorine in prevention of dental caries. J. A. Dent. A.,31:228.

------------, 1945. J. A. Coll. Dent.,12:60.

------------, and Ball, 1937. Quoted by Thoma, 1944.

Black, 1908. Operative Dentistry. Medical Dentistry Publishing Co.,1:75.

Bloomfield, A.L., 1919. Quoted by Topley and Wilson, 1936.

Box, 1924. Quoted by Goadby, 1931.

Branson, C.B., 1944. Practical fluorine therapy in dental caries control. J.A. Dent. A.,31:71.

Brawley, R.E., 1935. Studies on pH of normal resting saliva. Variations with age and sex. J. Dent. Res.,15:55.

Broadhurst, J., 1925. Bacteria in Relation to Man. Lippincott's Nursing Manuals. J. B. Lippincott, Philadelphia and London.

Bulloch, W., 1930. History of Bacteriology: A System of Bacteriology. Med. Res. Council, H. Maj. Stat. Off., London.

-----------, 1938. The History of Bacteriology. Oxford University Press, London, New York, and Toronto.

Bunting, R.W., 1930. Certain considerations in the problem of dental caries. Dent. Cosmos,72:399.

------------, 1933. Quoted by Thoma, 1944.

Burdon, K.L., 1939. A Textbook of Microbiology. The MacMillan Co., New York.

------------, 1939. Medical Microbiology. The MacMillan Co., New York.

Burrill, B.Y.,1943. Changes in caries susceptibility with age and sex. J. Dent. Res.,22:367.

Cannon, A.B., 1944. Dermatologic diseases involving the oral cavity. New York State J. Med.,44:1661.

Collins, Jensen, and Becks, 1942. Studies of caries-free individuals. J. A. Dent. A.,29:1169.

Crowley, M.C., and Richert, V.S., 1935. Amethod of estimating the bacterial content of the mouth by direct count. J. Bact.,30:395.

-------------, 1944. Actinomyces in normal mouth and infectious processes. A. J. Orth.,30:680.

Dobell C., 1918. Quoted by Goadby 1931.

----------, 1932. Antony von Leeuwenhoek and his "Little Animals". John Bale Sons and Danielson, Ltd., London.

Dodge, C.W., 1935. Medical Mycology. C.V. Mosby Co., St. Louis.

Dunning, H.S., 1931. Infections of the oral cavity. Bull. N.Y. Acad. Med., 7:14.

Emmons, C.H., 1937. Microaerophilic strains of actinomyces isolated in the tonsils. Mycoglia, 29:377.

Enright, Friesell, and Trescher, 1932. Quoted by Thoma, 1944.

Fancher, O.E., Calandra, J.C., and Fosdick, L.S., 1944. The effect of vitamins on acid formation in the saliva. J. Dent. Res., 23:23

Ford, W.W., 1927. Textbook of Bacteriology. W.B. Saunders Co. Philadelphia and London.

-----------, 1939. Bacteriology. Paul B. Hoeber Inc., Medical Book Department of Harper and Brothers, New York and London.

Fosdick, L.S., and Hansen, H.L., 1936. Theoretical considerations of carbohydrate degredation in relation to dental caries. J.A. Dent. A., 23:401.

--------------------------------, and Wessinger, G.D. 1937. The reductase activity of various mouth organisms. J. A. Dent. A., 24:1445.

Gay and Associates, 1935. Agents of Disease and Host Resistance. Charles C. Thomas, Springfield and Baltimore. Contributors: Benham, R.W. Rosebury, T., and Jungleblut, C.W.

Gies and Kliger, 1915. Quoted by Thoma, 1944.

Gins, H.A., 1934. Die nichtversporenden anaerobier der mundhole und der zahne.Zentralbl. f. Bakt. AbtI, 132:129.

Goadby, K.W., 1903. The Mycology of the Mouth. Longmans, Green and Co., London, New York, and Bombay.

-------------, 1931. Diseases of the Gums and Oral Mucous Membranes. Oxford University Press, New York, London and Toronto.

Grove, C.J., and C.T., 1935. Chemical studies of human saliva indicating that ammonia is an immunizing factor in caries. J. A. Dent. A.,22:247.

Gundel, E.M., and Linden, H., 1931. Flora of oral cavity of healthy persons. Role in pathogenesis of respiratory diseases. Zentralbl. f. Bakt.,121:349.

Hampp, E.G., 1945. Vincent's infection - a wartime disease. Observations on the oral spirochetal flora present in Vincent's infection. A. J. Pub. Health.,35:441.

Harris, R., 1942. Cysts of tonsillar fossae following tonsillectomy. Laryngoscope.,52:557.

Henrici, A. T., 1934. Molds, Yeasts and Actinomyces. John T, Wiley and Sons., New York.

--------------, 1934. The Biology of Bacteria. D.C. Heath Co. Boston.

Hine, M.K., and Bibby, B.G., 1939. Variations in the oral flora from time to time. J. Dent. Res.,18:61.

Hollander, 1936. Quoted by Thoma, 1944.

Hadley and Bunting, R., 1930. Bacillus acidophilus associated with dental caries. J. A. Dent. A.,17:2041.

Jay, P., 1929. Quoted by Thoma, 1944.

-------, 1946. Fluorine and dental caries. J. A. Dent.A. 33:489

-------, and Arnold, F.A., 1945. Epidemiological aspects of Lactobacillus counts in fluorine and non-fluorine areas. J. A. Coll. Dent.,12:54.

-------, Hadley, F.P., and Bunting, R., 1936. Observations on relation of Lactobacillus acidophilus in dental caries in in children during experimental feeding of candy. J. A. Dent. A.,23:846.

Johnston, Kaake, and Agnew, 1937. Quoted by Arnim, 1937.

Jordan and Falk, 1928. The Newer Knowledge of Bacteriology and Immunology. University of Chicago Press, Chicago. Contributors: Simonds, J.P.and Noguchi,H.

Jordan and Burrows, W., 1945. Text of Bacteriology. W. B. Saunders Co.,Philadelphia and London.

Kaiser, A.D., 1942. Effect of tonsillectomy on respiratory infections in children. Bull. of New York Acad. of Med. 18:388.

Kesel, R.G., O'Donnell, J.F.,and Wach, E.C., 1946. The biological production and therapeutic use of ammonia in the oral cavity in relation to dental caries prevention. J. A. Dent. A.,33:695.

Klalifah, E.S., 1937. Arabian description of dental caries in the tenth century. J. A. Dent. Res. and Dent. Cosmos,24:1847

Klein, 1932. Quoted by Arnim, 1937.

-----, 1943. Simplified technic for making pure cultures of oral spirochetes. Acta.Path. et Microbiol. Scandinavica,335.

Kligler, I.J., 1915. A biochemical study and differentiation of oral bacteria with special reference to dental caries. J. All. Dent. Soc.,10:141.

Lebron, A.P., 1936. Bacteriological study of normal throats and excised tonsils. Peurto Rico J. Pub. Health and Tropical Med.

Lewis, G.M., and Hopper, M. 1939. An Introduction to Medical Mycology. Year Book Publishers Inc., Chicago.

Liebertruth, E. 1935. Untersuchungen über das Bacterium Melaninogenicum. Zeitschr. Hyg. und Infect. 116:611

Lord and Emmons, 1933. Etiology, Pathology and Diagnosis of Actinomycosis. M. Clin. N. A.,16:29.

Lyons, D. C., 1935. Relation of certain aciduric bacteria and certain food elements to dental caries. J. A. Dent. A. 22:409.

Lyttle, J. D., 1942. Tonsillectomy in acute nephritis. Bull. New York Acad. Med., 365.

MacFarland, 1915. Pathological Bacteria and Protozoa. W.B. Saunders Co., Philadelphia and London.

MacNevin, M.S.,and Vaughan, H.S., 1933. Mouth Infections and their Relation to Systematic disease. Joseph Purcell Research Memorial, New York.

Marshall, J. S., 1916. Mouth Hygiene and Mouth Sepsis. J. P. Lippincott Co., Philadelphia and London.

Marziani, L., 1931. Normal Bacteriology. Stomatol, 29:105.

Mason, H.H., 1934. Personal observations on the after-effects of tonsillectomy. Laryngoscope, 44:784.

Maxcy, K.F., Phair, J.J., and Smith, M.R., 1942. Tonsillectomy as related to diphtheria rates in Baltimore. Am.J. Hyg., 35:42.

Miller, W.D., 1890. The Microorganisms of the Human Mouth. S.S. White Dental Mfg. Co., Philadelphia.

Morischita, T. 1929. Studies on dental caries, with special reference to aciduric organisms associated with the process; isolation and description of organisms. J. Bact., 18:181.

Naegeli, F. C.,and Morginson, W.J., 1945. Treatment of Vincent's Infection with penicillin. J. A. Dent. A., 32:1393.

Naeslund, C., 1925. Studies of actinomyces from the oral cavity. Acta Path. Microbiol. Scand., 2:110.

Park and Williams, 1939. Pathogenic Microorganisms. Lea and Febiger, Philadelphia.

Paton, J.H.P., 1943. Tonsil-adenoid operation in relation to health of group of schoolgirls. Quart. J., 12:119.

Pesch, K., und Schmitz, L., 1930. Untersuchungen über Zuchtung und systematik der "fusiform bacterium". Zentralbl. Bakt. Abt I, 136:476.

Pilot, I. 1944. Rapid identification of mucoid hemolytic streptococci of possible epidemic origin. J. A. M. A. 135:1037.

Prinz, 1927. Common diseases of oral mucous membrane. Dent. Cosmos, 69:53.

------, and Greenbaum, S.S., 1935. Diseases of the mouth and their treatment. Lea and Febiger, Philadelphia.

Riggall, C.W., 1934. Dental aspects of oral mycoses. Laryngoscope,44:35.

Rodriguez, F.E., 1930. Method of determining the incidence of *Lactobacillus odontolyticus* in the oral cavity. J.A. Dent. A.,17:1711.

----------------, 1931. Quantative incidence of *Lactobacillus acidophilus* in oral cavity as presumptive index of susceptibility to dental caries. J. A. Dent. A.,18:2118.

Rosebury, T., 1944. The parasitic actinomyces and other filamentous microorganisms of the mouth. Bact. Rev.,8:189.

-------------, 1944. Parasitic Lactobacilli. Arch. Path.,38:413.

Shaw, Elvehjan and Phillips, 1945. Survey of Incidence of dental caries in rhesus monkey. J. Dent. Res.,24.

Shelling, 1933. Quoted by Arnim, 1937.

Stephans, R.M., 1944. Intra-oral hydrogen ion concentration associated with caries activity. J. Dent. Res.,23:257.

Stitt, E.R., Clough, P.W. and Clough, M.C., 1938. Practical Bacteriology, Haemotology, and Animal Parasitology. P. Blakiston's Sons and Co. Inc.,Philadelphia.

Stuart, C.W., Knudson, W.,and Arnold, L., 1935. Self protecting mechanisms of the mouth against endogenous bacterial flora and movements of extrinsic organisms within the oral cavity. J. Dent. Res.,15:41.

Tanner, F.W., Lampert, E.,and Lampert, M., 1927. Presence of yeast-like fungi in normal throats. Zentralbl. f. Bakt.,103:94.

Taylor, F.S., 1942. The Conquest of Bacteria. Philadelphia Library, Philadelphia.

Thoma, K.H., 1944. Oral Pathology. C. V. Mosby Co., St. Louis.

Thomson, D. and Thomson, R.,1932. Common cold with special reference to the part played by streptococci, pneumococci, and other organisms. Ann. Pickett-Thomson Res. Lab.,8:1.

Todd, J.C., and Sanford, A.H., 1943. Clinical Diagnosis and Laboratory Methods. W.B Saunders Co., Philadelphia.

Topley, W.W.C., and Wilson, G.S., 1936. Principles of Bacteriology and Immunity. William Wood and Co.,Baltimore.

Tunnicliff, R., and Hammond, C., 1937. Presence of bacteria in pulps of intact teeth. J. A. Dent. A. and Dent. Cosmos, 24.

Turner, N. C., and Crane, E.M., 1944. Relationship between caries and saliva. J. Dent. Res.,23:413.

Ulicny, H.P., 1936. Some comparative studies of Lactobacillus acidophilus associated with dental caries. J. Dent. Res. 15:397.

Vonderlehr, R.A., 1937. Role of dentist in control of syphilis. J. A. Dent. A.,24:1935

Wach, E.C., Hine, M.K., Kesel, R.G., and O'Donnell, J. F., 1943. Testing caries activity by acid production in saliva. J. Dent. Res.,22:415.

Weisberger, J.D.R., 1946. J. Dent. Res.,25:83.

------------------, and Johnson, 1946. J. Dent. Res.,25:35.

Wheeler, S.W., Wilson, M.S., and Leash, M.M., 1936. Seasonal bacterial flora of the throat in rheumatic and non-rheumatic children. J. Clin. Invest.,14:325.

White, J., and Bunting, R.W., 1935. An investigation into the possible relationship of ammonia in the saliva to dental caries. J. A. Dent. A., 22:468.

Wihr, N.L., 1946. A comparison of methods of treating Vincent's infection. J. A. Dent. A.,33:721.

Wilbur, H.M., 1946. Treatment of Vincent's infection. J. A. Dent. A., 33:359.

Witkowski, R.W., 1935. Aerobe Mundhohlenflora bei Mutter und kind. Zentralbl. f. Bakt. Abt I,133:334.

Wohfeil, T. und Schulz, N.,1933. Vergleichende untersuçhungen uber die aerobe mikrobenflora bei zahngesunden und zahnkranken. Zentralbl. f. Bakt. AbtI,128:217.

Zank, M.,Bibby, B.G., and Berry, S., 1942. Studies on anti-bacterial factors of human saliva. Bio. Abst.

Zinsser, H. and Bayne-Jones, S., 1935. A Textbook of Bacteriology. D. Appleton-Century Co. Inc.,New York and London.

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